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CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANTS

OPTICAL FIBRE CABLES FOR DUCT, TUNNEL, AERIAL AND BURIED APPLICATION

ITU-T Recommendation L.10

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation L.10 was published in Volume IX of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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Recommendation L.10

OPTICAL FIBRE CABLES FOR DUCT, TUNNEL, AERIAL AND BURIED APPLICATION

(Melbourne, 1988)

Introduction

With the recent progress in optical fibre cable technology, optical fibres for telecommunication use have been applied to trunk and subscriber networks, indoor wiring and submarine sections. There are various kinds of installation, such as aerial, duct, cable tunnel, buried, on-premises and underwater. Thus, optical fibre cables are exposed to natural and man-made external factors.

There is a need to establish the mechanical and environmental characteristics of optical fibres which will satisfy operational requirements and to advise on suitable testing methods.

This Recommendation advises on optical cables to be used in certain installation conditions. Cables for underwater and in-building applications require further study.

1 Scope

This Recommendation:

- refers to multi-mode graded index and single-mode optical fibre cables to be used for telecommunications networks in duct, tunnel, buried and aerial installations;
- deals with mechanical and environmental characteristics of the optical fibre cables concerned. The optical fibre dimensional and transmission characteristics, together with their test methods, should comply with Recommendations G.651 and G.652, which deal with multi-mode graded index and single-mode optical fibres respectively;
- deals with fundamental considerations related to optical fibre cable from the mechanical and environmental points of view;
- acknowledges that some optical fibre cables may contain metallic elements, for which reference should be made to the manual, *Outside plant technologies for public networks* (see Recommendation L.1), and other L-Series Recommendations;
- recommends that an optical fibre cable should be provided with cable end-sealing and protection during cable delivery and storage, as is common for metallic cables. If splicing components have been factory installed they should be adequately protected;
- recommends that pulling devices can be fitted to the end of the cable if required.

2 Characteristics of the optical fibres and cables

2.1 *Mechanical characteristics*

2.1.1 *Fibre microbending*

Severe bending of an optical fibre involving local axial displacement of a few micrometers over short distances caused by localized lateral forces along its length is called microbending. This may be caused by manufacturing and installation strains and also dimensional variations of cable materials due to temperature changes during operation.

Microbending can cause an increase in optical loss. In order to reduce microbending loss, stress randomly applied to a fibre along its axis should be eliminated during the fiber's incorporation into the cable, as well as during and after cable installation.

2.1.1 *Fibre macrobending*

Macrobending is the resulting curvature of an optical fibre after cable manufacture and installation.

Macrobending can cause an increase in optical loss. The optical loss increases if the bending radius is too small.

2.1.3 *Cable bending*

Under the dynamic conditions encountered during installation, the fibre is subjected to strain from both cable tension and bending. The strength elements in the cable and the installation bend radius must be selected to limit this combined dynamic strain. Any fibre bend radius remaining after cable installation shall be large enough to limit the macrobending loss or long-term strain limiting the lifetime of the fibre.

2.1.4 *Tensile strength*

Optical fibre cable is subjected to short-term loading during manufacture and installation, and may be affected by continuous static loading and/or cyclic loading during operation (e.g. temperature variation). Especially in the case of aerial application, continuous loading during the full lifetime of the cable may be present. Fibre strain may be caused by tension, torsion and bending occurring in connection with cable installation and/or type of installation (e.g. aerial) and/or environmental conditions (e.g. wind, ice).

Excessive cable tensile loading increases the optical loss and may cause increased residual strain in the fibre if the cable cannot relax. To avoid this, the maximum tensile strength determined by the cable construction, especially the design of the strength member, should not be exceeded.

Note 1 – Where a cable is subjected to permanent loading during its operational life, the fibre should preferably not experience additional strain.

Note 2 – Aerial cable may be attached to a suspension wire. In this case, the strength member of the cable need only be designed to support the load during manufacture and installation.

2.1.5 *Crush and impact*

The cable may be subjected to crush and impact both during installation and operational life.

The crush and impact may increase the optical loss (permanently or for the time of application of the stress) and excessive stress may lead to fibre fracture.

In the case of self-supporting cylindrical aerial cables, the cable structure should be able to withstand the compression effects to prevent additional optical loss.

2.1.6 *Cable torsion*

Under dynamic conditions encountered during installation and operation, the cable may be subjected to torsion, resulting in residual strain of the fibres and/or damage of the sheath. If this is the case, the design of cable should allow a specified number of cable twists per unit length without an increase in fibre loss and/or damage to the sheath.

2.2 *Environmental conditions*

2.2.1 *Hydrogen gas*

In the presence of moisture and metallic elements, hydrogen gas may be generated. Hydrogen gas may diffuse into silica glass and increase optical loss. It is recommended that the hydrogen concentration in the cable, as a result of its component parts, should be low enough to ensure that the long-term effects on the increase of optical loss are acceptable.

By the use of dynamic gas pressurization, hydrogen absorbing materials, careful selection and construction (moisture barrier sheath) or elimination of metallic components, the increase in optical loss can be maintained within acceptable limits.

2.2.2 *Moisture permeation*

When moisture permeates the cable sheath and is present in the cable core, deterioration of the tensile strength of the fibre occurs and the time-to-static failure will be reduced. To ensure a satisfactory lifetime of the cable, the long term strain level of the fibre must be limited.

Various materials can be used as barriers to reduce the rate of moisture permeation. Alternatively, filled, metal-free cable constructions can be used.

Note – If required, minimum permeation is achieved by a longitudinal overlapped metallic foil. A continuous metallic barrier is effective to prevent moisture permeation.

2.2.3 *Water penetration*

In the event of damage to the cable sheath or to a splice closure, longitudinal penetration of water in a cable core or between sheaths can occur. The penetration of water causes an effect similar to that of moisture. The longitudinal penetration of water should be minimized or, if possible, prevented. Techniques such as filling the cable core with a compound, providing discrete water blocks or water swellable tapes, or providing unfilled cable with dry-air pressurization, may be applied to prevent water penetration.

Water in the cable may be freezed and, under some conditions, can cause fibre crushing with a resultant increase in optical loss and possible fibre breakage.

2.2.4 *Lightning*

Fibre cables containing metallic elements such as conventional copper pairs or a metal sheath are susceptible to lightning strikes.

To prevent or minimize lightning damage, consideration should be given to Recommendation K.21.

When a non-metallic cable is used, the cable should be filled and it should be protected against mechanical and thermal damage.

2.2.5 *Biotic damage*

The small size of an optical fibre cable makes it more vulnerable to rodent attack. Where rodents cannot be excluded, metallic protection should be provided. For further information reference should be made to Part IV-B, Chapter II of the manual *Outside plant technologies for public networks*.

2.2.6 *Vibration*

When optical fibre cables are installed on bridges they will be subject to relatively high amplitude vibrations of various low frequencies, depending on bridge construction and on the type of traffic density. Cables should withstand these vibrations without failure or signal degradation. Care should be exercised, however, in the choice of installation method.

Underground optical fibre cable may be subject to vibrations from traffic, railways, pile-driving and blasting operations. Here again, cables should withstand vibrations generated by these activities without degration.

A well established surveillance routine will identify the activity in order to make a careful choice of route to minimize this type of problem.

2.2.7 *Temperature variations*

During their operational lifetime cables may be subjected to severe temperature variations. In these conditions the increase of attenuation of the fibres shall not exceed the specified limits.

2.2.8 *Wind*

For optical fibre aerial cable, fibre strain may be caused by tension, torsion and vibration occurring in connection with wind pressure. Induced dynamic and residual strain in the fibre may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded.

To suppress any fibre strain induced by wind pressure, the strength member should be selected to limit this strain to safe levels, and the cable construction may mechanically decouple the fibre from the sheath to minimize the strain. Alternatively, to suppress fibre strain the cable may be lashed to a high strength support strand.

In aerial installations winds will cause vibrations and, in figure-of-eight and suspension wire installations, severe oscillations of the entire span of the cable may occur. Cables should be designed and/or installed to provide stability of the transmission characteristics in these situations.

2.2.9 *Snow and ice*

For optical fibre aerial cable, fibre strain may be caused by tension occurring in connection with snow loading and/or ice formation around the cable. Induced fibre strain may cause excess optical loss and may cause fibre breakage if the specified long-term strain limit of the fibre is exceeded.

Dynamic strain in the fibre may be induced by vibration caused by the action of snow and/or ice falling from the cable. This may cause fibre breakage.

Under the load of snow and/or ice, excessive fibre strain may easily be induced by wind pressure.

To suppress the fibre strain by snow loading and/or ice formation, the strength member should be selected to limit this strain to safe levels, and the cable profile may be selected to minimize snow loading. Alternatively, to suppress fibre strain the cable may be lashed to a high strength support strand.

2.2.10 *Strong electric fields*

Metal-free aerial cables installed on high voltage power lines are susceptible to the influence of the electric field of these power lines which may lead to phenomena such as corona, arcing and tracking of the cable sheath.

To prevent damage, special cable sheath materials may have to be used depending on the level of electric field.

3 Cable construction

3.1 *Fibre coatings*

3.1.1 *Primary coating*

Silica fibre itself has an intrinsically high strength, but its strength is reduced by surface flaws. A primary coating must therefore be applied immediately after drawing the fibre to size.

The optical fibre should be proof-tested. In order to guarantee long-term reliability under service conditions, the proof-test strain may be specified, taking into account the permissible strain and required lifetime.

In order to prepare for splicing, it should be possible to remove the primary coating without damage to the fibre, and without the use of materials or methods considered to be hazardous or dangerous.

The composition of the primary coating, coloured if required, should be considered in relation to any requirements of local light-injection and detection equipment used in conjunction with fibre jointing methods.

Note 1 – The coating should have a nominal diameter of 250 µm.

Note 2 – The primary coated fibres should be proof tested with a strain equivalent to at least 0.5% for a duration of one second. The test method should be in accordance with IEC publication 793-1 [1]. For aerial cable applications, taking into account large thermal changes and strong winds, a larger proof-test strain may be necessary.

Note 3 – Further study is required to advise on suitable testing methods for local light-injection and detection.

3.1.2 *Secondary protection*

Secondary protection of the fibre within the cable should be provided.

Note 1 – Methods of secondary protection are described in the manual on the construction, installation, jointing and protection of optical fibre cables [2].

Note 2 – When a tight secondary coating is used it may be difficult to use local light-injection and detection equipment associated with fibre jointing methods.

Note 3 – To limit axial fibre stress, the mechanical coupling between fibre and cable should be minimized.

3.1.3 *Fibre identification*

Fibre should be easily identifided by colour or position within the cable core. If a colouring method is used, the colours should be clearly distinguishable and have good colour-fast properties also in the presence of other materials, during the lifetime of the cable.

3.1.4 *Splicing properties*

Further study is required to advise on suitable testing methods for local light-injection and detection.

3.2 *Cable core*

The make-up of the cable core, in particular the number of fibres, their method of protection and identification, the location of strength members and metallic wires or pairs, if required, should be clearly defined.

3.3 *Strength member*

The cable should be designed with sufficient strength members to meet installation and service conditions so that the fibres are not subjected to excessive strain.

The strength member may be either metallic or non-metallic and may be located either in the cable core and/or in the sheath.

For example, in the metal-free self-supporting aerial cable the strength member may consist of a layer of aramid yarns located between the inner sheath and the outer sheath, or of a single glass-fibre reinforced strand in a figure-of-eight construction. A knowledge of span, sag, wind and ice-loading is necessary to design such a cable.

3.4 *Water-blocking materials*

Filling a cable with water-blocking material is one means of protecting the fibres from water ingress. Any materials used should not be harmful to personnel. The materials in the cable should be compatible, one with the other, and in particular should not adversely affect the fibre performance, or any identification colours of the fibres.

In addition, the material should be non-nutritive to fungus, and be electrically non-conductive, homogeneous and free from contamination.

3.5 *Pneumatic resistance*

If the cable requires dry air pressurization during operation, the pneumatic resistance should be specified.

Note – It is intended that a cable can be pressurized only if it allows a flux of air which is in accordance with the criteria defined in Part III of the manual *Outside plant technologies for public network* (see Recommendation L.1).

3.6 *Sheath*

The cable core should be covered with a sheath suitable for the relevant environmental and mechanical conditions associated with storage, installantion and operation. The sheath may be of a composite construction and may include strength members.

Sheath considerations for optical fibre cables are generally the same as for metallic conductor cables. Consideration should also be given to the amount of hydrogen generated from a metallic moisture barrier. The minimum acceptable thickness of the sheath should be stated, together with any maximum and minimum allowable overall diameter of the cable.

Note 1 – One of the most sheath materials is polyethylene. There may be however, some environmental conditions where it is necessary to minimize the flammability of a cable and limit the emission of fumes, smoke and corrosive products. Special materials should be used for the cable sheath in these situations.

Note 2 – For directly buried cables installed in areas with chemically contaminated soils (acids, hydrocarbons, etc.), specially designed cable sheath combinations may be used.

Note 3 – In the case of aerial cables, the outer sheath should be resistant to the degradation due to ultraviolet radiation.

3.7 *Armour*

Where additional tensile strength or protection from external damage is required, armouring should be provided over the cable sheath.

Armouring considerations for optical fibre cables are generally the same as for metallic conductor cables. However, hydrogen generation due to corrosion must be considered. It should be remembered that the advantages of optical fibre cables, such as lightness and flexibility, will be reduced when armour is provided.

Armouring for metal-free cables may consist of aramid yarns, glass fibre reinforced strands or strapping tape, etc.

3.8 *Identification of cable*

If a visual indentification is required to distinguish an optical fibre cable from a metallic cable, this can be done by visibly marking the sheath of the optical fibre cable.

4 Test methods

4.1 *Test methods for mechanical characteristics*

This section recommends appropriate tests and test methods for verifying the mechanical characteristics of optical fibre cables.

4.1.1 *Tensile strength*

This test method applies to optical fibre cables installed under all environmental conditions.

Measurements are made to examine the behaviour of the fibre attenuation as a function of the load on a cable during installation.

The test should be carried out in accordance with method IEC 794-1-E1 [3].

The amount of mechanical decoupling of the fibre and cable can be determined by measuring the fibre elongation, with optical phase shift test equipment, together with the cable elongation.

This method may be non-destructive if the tension applied is within the operational values.

4.1.2 *Bending*

This test method applies to optical fibre cables installed under all environmental conditions.

The purpose of this test is to determine the ability of optical fibre cables to withstand bending around a pulley, simulated by a test mandrel.

This test should be carried out in accordance with method IEC 794-1-E11 [3].

4.1.3 *Bending under tension (flexing)*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study.

4.1.4 *Crush*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E3 [3].

4.1.5 *Squeezing (abrasion)*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study, and is currently under consideration in the method IEC 794-1-E2 [3].

4.1.6 *Torsion*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E7 [3].

4.1.7 *Impact*

This test method applies to optical fibre cables installed under all environmental conditions.

This test should be carried out in accordance with method IEC 794-1-E4 [3].

4.2 *Test methods for environmental characteristics*

This section recommends the appropriate tests and test methods for verifying the environmental characteristics of optical fibre cables.

4.2.1 *Temperature cycling*

This test method applies to optical fibre cables installed under all environmental conditions.

Testing is by temperature cycling to determine the stability of the attenuation of a cable due to ambient temperature changes which may occur during storage, transportation and operation.

This test should be carried out in accordance with method IEC 794-1-F1 [3].

Note – For aerial self-supporting cables, the stability of the attenuation may be measured with a specified tension applied to the cable sample.

4.2.2 *Longitudinal water penetration*

This test method applies to completely filled outdoor cables installed under all environmental conditions. The intention is to check that all the interstices of a cable are continuously filled with a compound to prevent water penetration within the cable.

This test should be carried out in accordance with method IEC 794-1-F5 [3].

4.2.3 *Moisture barrier*

This test method applies to optical fibre cables installed under all environmental conditions.

This test applies to cables supplied with a longitudinal overlapped metallic foil. The moisture penetration can be tested according to the test method as described in Part I, Chapter III of the manual *Outside plant technologies in public networks* (see Recommendation L.1).

4.2.4 *Freezing*

This test method applies to optical fibre cables installed under all environmental conditions.

This subject needs further study and is currently under consideration in the method IEC 794-1-F6 [3].

4.2.5 *Hydrogen*

This test method applies to optical fibre cables installed under all environmental conditions.

A suitable short-duration test procedure needs to be determined for the factory complete cable, so that the results of factory tests enable the long-term increase in fibre loss to be predicted.

4.2.6 *Nuclear radiation*

This test method assesses the suitability of optical fibre cables to be exposed to nuclear radiation.

This subject needs further study and is currently under consideration in the method IEC 794-1-F7 [3].

4.2.7 *Vibration (bridge and underground cables)*

This test method assesses the suitability of optical fibre cables for bridge and underground application.

This subject needs further study.

4.2.8 *Vibration (aerial cables)*

This test method assesses the suitability of optical fibre cables for aerial application.

The subject needs further study.

4.2.9 *Ultraviolet resistance*

This test method applies to aerial optical fibre cable and assess the suitability of the cable sheath to withstand ultraviolet radiation.

This subject needs further study.

4.2.10 *Sheath tracking*

This test applies to aerial optical fibre cables used on high voltage power lines.

This subject needs further study.

References

[1] IEC publication 783-1 *Optical fibres, Part 1: Generic specifications*, Geneva, 1987.

[2] CCITT manual *Construction, installation, jointing and protection of optical fibre cables*, ITU, Geneva, 1985.

[3] IEC publication 794-1 *Optical fibre cables*, *Part 1: Generic specifications*, Geneva, 1987.